SOUTHERN OCEAN GLOBAL OCEAN ECOSYSTEMS DYNAMICS (SO GLOBEC)

GLOBEC researchers prepare to collect blood samples from a crabeater seal on the sea ice in Marguerite Bay off the Antarctic Peninsula.
(NSF photo)

The goal of the U.S. Global Ocean Ecosystems Dynamics (U.S. GLOBEC) program is to understand and ultimately predict how populations of marine animal species respond to changes in climate, both natural and anthropogenic. Research in the Southern Ocean indicates a strong coupling between climatic processes - via the annual formation and destruction of sea ice - and ecosystem dynamics. As participants in the Southern Ocean GLOBEC program (SO GLOBEC), we will investigate the dynamic relationship between physical processes and ecosystem responses by identifying critical parameters that affect the distribution, abundance, and population dynamics of target species. Overall, we hope to elucidate shelf circulation processes and their effect on sea-ice formation and antarctic krill (Euphausia superba) distribution, and to examine the factors that govern how krill survive and become available to higher trophic levels (including penguins, seals, and whales). To accomplish this we use moored-instrument investigations; broad physical, biological, and chemical oceanographic surveys; process-oriented investigations; and modeling studies focused on austral winter processes in the western Antarctic Peninsula region.

We have chosen Marguerite Bay in the central western Antarctic Peninsula continental shelf, which is characterized by unusually high krill production. We hypothesize that these high production levels result from a unique combination of physical and biological factors that enhance krill growth, reproduction, recruitment, and survivorship throughout the year.

Water masses on the continental shelf off Marguerite Bay consist of inflowing Upper Circumpolar Deep Water, which is relatively warm, salty, oxygen-poor, and nutrient-rich. In winter, atmospheric processes cool and freshen this water and recharge it with oxygen to produce Antarctic Surface Water. This austral winter environment also provides particularly favorable conditions for larval and adult krill survival, including

• a shelf circulation that keeps the krill population in a favorable environment for extended periods;

• a persistent, winter ice cover that provides dependable food and protection for larval krill to grow and survive over the winter; and

• on-shelf intrusions of Upper Circumpolar Deep Water, supplying heat, salt, and nutrients that affect ice properties and enhance biological production.

Making use of the U.S. Antarctic Program's two research ships - the icebreaking research ship Nathaniel B. Palmer and the ice-strengthened research ship Laurence M. Gould - we will continue our 2-year field study in mid-March 2002 (the late austral fall). Working in the Antarctic Peninsula region until mid-August 2002, we will conduct five cruises aboard the two ships in and around Marguerite Bay. The results of the integrated SO GLOBEC program will improve our power to predict the fate and condition of living marine resources, especially with respect to local and global climatic shifts.

Southern Ocean GLOBEC: Circulation and water property evolution.
Robert Beardsley and Richard Limeburner, Woods Hole Oceanographic Institution.

As part of the Southern Ocean GLOBEC program, we will develop and deploy on the continental shelf off Marguerite Bay a series of moorings, including current meters, sensors to measure salinity, temperature and zooplankton concentration, upward-looking acoustic sounders to track ice motion, and acoustic Doppler current profilers. Our proposed mooring design will quantify and characterize the inflowing and outflowing water masses, and provide the physical component for the integrated modeling effort. Instrumented drifters will supplement the mooring data. These data should quantify the spatial and temporal variability of the (presumed) clockwise flow of water masses through the bay, and help to define the tidal and transient flows driven by storms and southward meanders of the Antarctic

Circumpolar Current.

Southern Ocean GLOBEC: Mesoscale circulation, tides and mixing.
Lawrence Padman, Earth and Space Research.

Our project has three major components:

• to collect, analyze, and archive Acoustic Doppler Current Profiler (ADCP) and Conductivity-Temperature-Depth (CTD) data - in order to characterize mesoscale circulation features and the regional hydrography;

• to develop an accurate model of tidal currents in Marguerite Bay; and,

• to provide a data set of small-scale processes (such as shear instabilities, tidal stirring, mesoscale eddies, and double diffusion) that are required to establish effective parameters for the vertical movement of heat, salt, and nutrients.

The results of our project will provide a unified data base, linking water column and sea-ice processes with the biology of krill and its predators.

Southern Ocean GLOBEC: Water column microstructure.
Thomas Powell, University of California, Berkeley.

Collecting data on the small-scale temperature and salinity structure of the ocean's surface layer, we will study the effect of stratification and turbulence on the biochemical and biological processes under the winter sea ice. These modification processes work through mixing that is associated with shear instabilities of the internal wave field, double diffusion of salt and heat, and mixing driven by surface stress and convection. We will use two microstructure profilers to resolve the small, but crucial, vertical variations that drive these processes.

Southern Ocean GLOBEC: Hydrography and biological and physical modeling.
Eileen Hofmann, John Klinck and Ricardo Locarnini, Old Dominion University.

We have two objectives - to characterize the regional hydrography and to develop a hierarchy of models to organize and integrate physical and biological observations. With repeated regional surveys for temperature, salinity, nutrients, and oxygen, we will define the water masses in the Marguerite Bay region. Also, data will be collected with a moored current-meter and temperature array, as well as by acoustic surveys of the upper ocean current structure. Through models, we will link water column and sea-ice processes with the biology of krill and its predators. Three types of models will be used to synthesize physical and biological models over the continental shelf - time-dependent biological models, depth-time models of physical and biological characteristics, and three-dimensional and time-dependent models.

Southern Ocean GLOBEC: Sea ice physics.
Douglas Martinson, Lamont-Doherty Earth Observatory; Raymond Smith, University of California, Santa Barbara; Donald Perovich, U.S. Army's Cold Regions Research and Engineering Laboratory.

The optical properties of snow and sea ice evolve over the winter and vary greatly, both spectrally and spatially. These properties are important elements of the physical environment and strongly influence the distribution of - and the resources available to - antarctic krill. The intensity and distribution of incident radiant energy within the snow, ice, and water column - and the linked physical, optical, chemical, and biological processes that modulate its distribution - are known, but poorly quantified. These properties also impact both predator and prey, influencing snow and ice algae, water-column productivity and visibility. They are also essential in satellite observations as proxy indicators of geophysical sea-ice parameters. To follow the temporal and spatial evolution of this snow and ice marine ecosystem, we will try to create improved quantitative models, deploying an array of instrumented ice beacons, augmented by periodic, ship-based and satellite observations and by theoretical studies.

Southern Ocean GLOBEC: Dissolved nutrients and oxygen measurements.
Kent Fanning, University of South Florida.

Our project focuses on providing high quality measurements of water-column silica, phosphate, nitrite and nitrate concentrations, as well as dissolved oxygen. These measurements will be examined in conjunction with the marine biological and physical oceanography components.

Southern Ocean GLOBEC: Primary production in the water column.
Maria Vernet, Scripps Institution of Oceanography, University of California, San Diego.

Focusing on primary production in the water-column, we will use direct experimental estimates, modeling results from a fast-repetition-rate fluorometer, and modeling of primary production from optical as well as biophysical models. This research will be coordinated with components focused on sea-ice production and sea-ice habitats.

Southern Ocean GLOBEC: Sea-ice microbial communities.
Christian Fritsen, Desert Research Institute; University of Nevada.

Focusing on the distribution and activities of sea-ice microbial communities, we will use an integrated combination of sampling (vertical profiles, horizontal surveys, and under-ice surveys) and observational protocols. Experiments will be designed to estimate microbial activity within the sea ice and at the ice/seawater interface. We will coordinate our research with components studying the water-column productivity and the sea-ice habitat.

Southern Ocean GLOBEC: Water column krill distribution and abundance in winter.

Meng Zhou, University of Minnesota.

We will use acoustic techniques to acquire data on the distribution of juvenile and adult krill and mesozooplankton prey. We will also study krill shrinkage and mortality rates, and krill aggregation behavior. The results will be analyzed in coordination with components using other physical and biological models.

Southern Ocean GLOBEC: Zooplankton distribution and abundance.
Peter Wiebe, Carin Ashjian, Cabell Davis, and Scott Gallager; Woods Hole Oceanographic Institution.

This project will focus on juvenile and adult krill and mesozooplankton prey-distribution and abundance, using a sophisticated instrument package, BIOMAPPER II. The instruments in the package include an acoustic backscatter sonar system, a video plankton recorder and an environmental sensor system. We will use a remotely-operative vehicle to map the distribution and behavior of krill under ice.

Southern Ocean GLOBEC: Winter ecology of larval krill.
Robin Ross and Langdon Quetin, University of California, Santa Barbara.

Focusing on the under-ice distribution and abundance of larval and juvenile krill, we will assess the physiological condition of krill associated with areas of sea ice that provide food of differing quality and quantity. In an effort to understand the overall age-specific dynamics of krill in winter, we will coordinate with krill study components focusing on adults in the water column.

Southern Ocean GLOBEC: Krill physiology, distribution, predation and fish ecology.
Jose Torres and Kendra Daly, University of South Florida.

This project will focus on krill physiology, using measures of respiration, excretion, and proximate analysis. We will conduct feeding experiments using various measurement techniques. Under-ice surveys and sample collection will provide information on krill abundance and distribution. Also, we will investigate the distribution and abundance of fishes and squid - krill predators - using acoustic and net-tow methods.

Southern Ocean GLOBEC: Biochemical determination of age and dietary history in the krill.
H. Rodger Harvey, Center for Environmental Sciences, University of Maryland.

To determine the population/age structure of krill in field populations (over seasonal and interannual time scales), and to establish markers for dietary history, we will apply new biochemical approaches based on lipids that are specific to different food resources. This research will be coordinated with components studying krill feeding and growth.

Southern Ocean GLOBEC: Seabird distribution and abundance in winter.
Christine Ribic, University of Wisconsin; William Fraser, Montana State University.

Our project focuses on large-scale distribution, abundance, and habitats of seabirds, as well as on the composition of the seabird diet and on small-scale foraging behavior. To accomplish this, we will use strip-transect surveys and examine large-scale data with spatial analysis software and models. We will also use satellite transmitters to correlate foraging behavior with diet studies.

Southern Ocean GLOBEC: Foraging ecology of crabeater seals.
Daniel Costa and Daniel Crocker, University of California, Santa Cruz; Jennifer Burns, University of Alaska, Anchorage.

Using a combination of satellite-linked tracking, specialized diver-recorders, and stable isotopic tracers, we will focus on the distribution and foraging behavior of adult female crabeater seals. These data will be coordinated with other study components focused on prey (krill) distribution and the physical environment. The results will be analyzed using an optimality model.

Southern Ocean GLOBEC: Mysticete whale acoustic census in the GLOBEC west antarctic project area.
John Hildebrand, Scripps Institution of Oceanography, University of California, San Diego.

We will determine minimum population estimates, distribution, and seasonality for mysticete whales, especially blue whales, by using passive acoustic recorders deployed on the seafloor for 1 to 2 years. The deployment of a large-aperture, autonomous, hydrophone array in the antarctic will use passive acoustics as a tool to detect and count mysticete whales.

Southern Ocean GLOBEC: Modeling the effects of eddies and mean flows on Southern Ocean biology.
Glen Flierl, Massachusetts Institute of Technology.

Our objective is to understand the interactions of biological and physical dynamics by modeling the spatial distribution of krill, which form dense aggregations (or patches) on the small scale. The spatial distribution of these patches apparently depends on:

• the advance and retreat of sea ice;

• the three-dimensional movement of water masses - from small-scale turbulence to the dynamics of the Antarctic Circumpolar Current; and

• the pressure of the food supply and predation.

Earlier studies indicate that physical processes dominate on the larger scale, while biological processes dominate on the smaller scale. The relative importance of the two as a function of scale, however, has not been investigated systemically. To accurately represent patchiness in a circumantarctic model, we will study a detailed model that can resolve the scale of krill patches and help us to analyze and understand the field observations. These results will allow us to improve the parameters of krill distributions in meso-scale and

basin-scale models of the Southern Ocean.

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